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Ocularity and adaptation in a depth discrimination task

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Abstract

Depth perception and adaptation, as related to ocularity, are the topics of this experimental study. Subject samples consist of three groups- one binocular, one composed of unilaterally occluded binocular subjects, and one composed of two adapted monocular patients (one eye enucleated). Both speed and accuracy were measured using a modified Howard Dolman apparatus. Binocular individuals demonstrated significantly better performance than occluded binocular subjects in both accuracy and a measure of JND. There was no significant difference in speed of judgment between groups. Due to the small sample of adapted monocular subjects and their variable performance, no generalizations can be drawn from their results. Individual results are discussed as are implications for further research.

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BIOGRAPHY

Brian Duvall is a 1990 graduate of Central Washington University. He possesses a Bachelor of Arts Degree in Biology, with minors in zoology and chemistry. He will receive his Doctor of Optometry from Pacific University College of Optometry upon commencement in May, 1994.

Functionally monocular himself, Brian endeavors to more fully understand all aspects of monocular performance. Also being an accomplished athlete, he plans to apply the concepts of vision enhancement with the purpose of improving athletic performance of all athletes, professional and recreational.

Upon graduation, Brian has accepted a resident fellowship in the treatment and management of ocular pathology at OMNI Eye Specialists, Denver, Colorado. After completing the fellowship, he plans to establish a full scope private practice in his hometown of Federal Way, Washington, with the long term goal of gaining clinic directorship at a co-management referral center in the area of ocular disease.

This work is dedicated to

all the individuals who are fortunate enough

to have vision in one eye -

and this unique perspective from which to see the world

I am inspired by their refusal to accept their circumstance as a handicap,

being limited instead only by the goals they set,

and their willingness to work to reach them.

ACKNOWLEDGMENTS:

I wish to thank all those people who contributed the energy to power this project:

Rena Hoefling, Chief, Restoration Clinic, Veterans Administration Medical Center, Portland, Oregon for her invaluable effort in locating the monocular patients; Michelle Newell, Vision Therapy Coordinator, Pacific University Family Vision Centers for her efforts in scheduling; A special thanks to my advisor, Dr. Bradley Coffey, whose experience, guidance, time, and fine attention to detail shaped my vision and enthusiasm into the successful venture it became; And finally, to all my family and friends for their love, support and patience that outlasted all my tirades and helped me to protect my sanity.

Table of Contents

ABSTRACT:

Depth perception and adaptation, as related to ocularity, are the topics of this experimental study. Subject samples consist of three groups - one binocular, one composed of unilaterally occluded binocular subjects, and one composed of two adapted monocular patients (one eye enucleated). Both speed and accuracy were measured using a modified Howard Dolman apparatus. Binocular individuals demonstrated significantly better performance than occluded binocular subjects in both accuracy and a measure of JND. There was no significant difference in speed of judgment between groups. Due to the small sample of adapted monocular subjects and their variable performance, no generalizations can be drawn from their results. Individual results are discussed as are implications for further research.

INTRODUCTION:

The primary concern of the optometric and ophthalmologic professions is to provide for each individual the most efficient, sensitive, and healthy visual system possible. Stereopsis is a cornerstone of efficient binocular visual function. However, the emphasis placed upon stereopsis has caused the functional value of monocular depth perception to be overlooked and consequently misunderstood within the field of eye care.

Each year approximately 50,000 individuals in the United States join the monocular population[1] and must rely solely on monocular information for their adaptation to everyday living. The primary adaptation is the refined interpretation of the monocular depth cues of interposition, linear perspective, texture, shadowing, relative size and motion parallax. The latter two provide the most information[2] for relative spatial judgments.

The performance and limitations of monocular individuals and the monocular visual system was studied somewhat intensively earlier this century. After a time of relatively little activity, there has been a resurgence in this area of research. The study of the monocular system holds many important implications. Foremost are the benefits to the large monocular population, both in proper education of patients and vision care providers. Furthermore, the possibility of training and enhancement of visual function for these individuals can not be disregarded. Sheedy, et. al[3], showed the possibility of binocular enhancement through purely monocular input, again touching on an intriguing application which may reach an even greater population.

Unfortunately, the results of many studies and their application to larger populations have been hampered by two major limitations. First, the designs often focus upon specific and rather complicated tasks, such as driving a tractor trailer or landing an aircraft [4,5,6,7]. This limits the generalizations which can be made to other tasks. Logically, one must first study the general workings of a sensory system, apply those results to a more natural setting, then finally see the results applied to complex tasks. This provides a solid foundation from which to draw conclusions. The second limitation encountered in the literature is the use of monocularly-occluded binocular individuals as an experimental sample instead of true monocular subjects[3,6,7,11]. Though yielding some useful information, these experimental samples are not an accurate representation of the monocular population as a whole and, therefore, do not allow for generalization beyond a limited scope. In other words, a binocular occluded population provides good insight to the short term adaptations and performance of individuals who have recently become monocular. The results can not, however, be likened to the monocular population and the adaptations achieved by them over time.

Von Noorden brings light to this fact in his account of a monocular patient who stumbles drastically at first but "in time may overcome these difficulties and become as skillful as or almost as skillful as before the eye was lost". He further states that this includes near tasks where previously stereoscopic cues were relied upon almost entirely[8]. Brady proposes an increase in concentration as a possible factor related to comparatively greater task performance following the loss of an eye[1].

Finally, in a study titled "Why two eyes are better than one...", Jones and Lee[9] showed that when subjects were allowed to move their heads freely, representing a more realistic viewing situation, "stereopsis was not found to be important in the performance of visuomotor skills in the presence of three dimensions." Gonzalez et al.[10] found that the use of motion parallax significantly improved the accuracy of both monocular and binocular individuals, though the adaptation to employ motion parallax in the absence of stereopsis was slow to develop. Though historically there has been debate as to which monocular cue is of greatest importance (i.e. static cues such as relative size difference or dynamic cues such as motion parallax), the necessity of using some or all of these cues in the absence of binocular disparity is certain. Therefore, it has been shown that other means are available which can be used effectively and accurately as keys to spatial perception when stereopsis is not available.

The experimental design used in this study can be extrapolated to a wider array of applications, while also accurately portraying the long term adaptive mechanisms of the monocular population. It is hypothesized that the adapted monocular individual will show performance as accurate but slightly less efficient compared to binocular subjects. Both populations are hypothesized to score significantly better than binocular individuals with short term occlusion of one eye.

METHODS:

Subjects:

Three subject groups were asked to complete the spatial judgment task. All participants wore the appropriate prescription that yielded the best visual acuity. Also, all subjects had their distance stereopsis prescreened using the Mentor Binocular Visual Acuity Tester (B-VAT) prior to beginning the experiment.

The first experimental group included two individuals (M1 and M2) having one eye, the other having been enucleated. Subject M1 is a 79 year old male whose right eye was enucleated 50 years ago. Subject M2 is a 70 year old male whose left eye was enucleated 48 years ago. The second two experimental populations consisted of binocular individuals from the Pacific University community who volunteered to participate in the study and were randomly assigned to two groups. The first group, containing eighteen individuals was tested with one eye occluded by means of patching their non-preferred sighting eye (Group OB). Group OB consisted of three males and fifteen females with an average age of 24.9 years. A second group of twenty-one binocular participants remained unoccluded, making full use of binocular vision (Group B). Group B consisted of ten males and eleven females with an average age of 24.3 years. No compensation was given to any subject for their participation in the research project. Finally, all participants completed a consent form (see Appendix A) before testing procedures were administered.

Inclusion criteria required a minimum age of six years, best compensated six meter monocular visual acuity of at least 20/30, and the capability to perform subjective testing procedures. Further, binocular subjects to eligible for participation in either Group OB or Group B were required to demonstrate at least 240 seconds of arc distance stereoacuity on the B-VAT.

Apparatus / Instrumentation:

The device used to measure the experimental dependent variable utilizes a number of modifications of the standard Howard - Dolman apparatus (Refer to Appendix B, Figures 1.0 - 6.0). These modifications improve the experimental procedure by providing the viewer with more realistic cues to depth and constant interior lighting, while eliminating kinesthetic feedback by way of an electric remote control.

The external appearance of the apparatus shows three major parts. The first is the main rectangular housing (Figure 1.0). The bottom, and one long side of the housing have no openings. The smaller front and rear end pieces contain only small round openings, through which electrical cables run; the front opening for the remote cable, and the rear opening for the power supply. The opposite long side (Side B) has a narrow opening running most of its length, as well as two toggle switches attached to its surface. One switch is an on/off switch for the lighting; the other controls the internal motor. The narrow slit allows for a pointer that indicates experimental measurements. The second major part, a ruled scale, attaches just below the long, narrow opening on the side of the device through which the measuring needle protrudes.

The scale is graded in millimeters and has a central "zero" point that corresponds to the position of the stationary target. Extending to both sides of the "zero" point, the millimeter scale reads to a maximum of 25 centimeters in each direction. The measuring needle runs just above the scale, thus allowing the examiner an accurate and easily read measurement.

The top side of the rectangular housing (Side C) contains another long, narrow opening, offset from the center, which creates a groove through which a movable target runs. Centered along the length, and equally offset from midline, is mounted a stationary target (Figure 4.0). The targets are discussed in greater detail later within this section. All sides with the exception of the top side are painted white; the top being painted flat black.

The last of the three main external pieces is the top, or hood, of the instrument (Figure 2.0). Constructed of metal and having a uniform curvature along its length, it fits snugly over the top of the wooden housing. The back has no opening. The front has a small rectangular cut - out. Thus, when the hood is securely fastened over the top of the housing, there exists only the small opening in the front through which the subject can view the targets. The entire outside surface of the hood is painted white. There is a small black border around the opening to provide maximum contrast of the targets. The inner surface, with the exception of the back is painted a uniform white; the inner surface of the back is painted flat black. A removable door was attached with tape to cover the view opening during experimentation. This door can be easily moved to allow proper viewing of the targets when testing, and to hide the targets when data are being recorded, thereby denying feedback to the subject.

There are two targets contained within the unit, one stationary and the other movable. Unlike the standard vertical rods of the original Howard - Dolman apparatus, these targets are simply standard white golf balls. These targets were chosen because they accentuate the monocular cues of shadow and texture seen and utilized during everyday judgments of object depth. The targets are maximally contrasted within the experimental device by placing them above the black surface of the housing, and in front of the black backdrop of the hood (Figure 3.1). The targets' side-by-side separation is 60 millimeters, and each is offset an equal distance from the midline of the unit. The stationary target is mounted directly to the top piece of the wooden housing. The variable target is mounted via a small post, through the corresponding groove, where it is attached to a carrier underneath.

Lighting for the targets is provided internally by two fluorescent strip lights mounted atop the wooden housing, running the length of the device. The lights are placed parallel to the track of the variable target, to the extreme sides of the device. The view opening is positioned such that these lights cannot be seen by the subject when positioned at the correct testing distance. The internal light is therefore evenly reflected throughout the interior of the hood, providing equal illumination on each target, no matter what the position of the variable target.

As previously mentioned, the variable target was attached to a carrier lying below the wooden top piece (Side C). This carrier is actually a small rectangular piece of wood that moves along a track of three small diameter rods. This track runs the length of the device parallel to the groove cut in the top of the wooden housing (Figure 5.0). Friction between the carrier and the metal rods is reduced by metal sleeves inside the carrier.

A motor and pulley system is used to move the carrier and its attached target along the track. The motor utilized is a reversible, low speed gear motor with an attached pulley. The direction of the motor can be controlled by a switch mounted in the wooden housing or a switch located in the hand held remote. The speed of the motor can only be altered by the use of a rheostat knob mounted in the remote.

The motor was attached to the carrier through the use of a non-continuous rubber belt, made of small diameter heater hose. This type of belt was found to be best at providing the necessary tension and friction on the pulley without slippage. The belt is driven by the main pulley attached directly to the motor. Each belt end is wound through its own respective pulley system, located at each end of the track (Figure 6.0). The belt ends are then attached to the carrier via a clamp. This clamp allows for easy tightening of the belts should they stretch over time. Electronic "kill" switches are also placed at each end of the track. These switches act to turn off the motor when the carrier reaches them to avoid any damage to the motor or any part of the system.

This modified version of the original Howard - Dolman apparatus is designed to be controlled by means of an electric remote. In this manner, all kinesthetic feedback due to the original subject-controlled, string-driven device is eliminated. Therefore, subjects must rely solely on visual input. The electric remote is simple to operate, having only two controls. The first is a toggle switch. Set in the appropriate position, this switch determines which direction the variable target will move along its track - either towards the subject or away from him. Located next to the toggle switch is a rheostat knob. This knob is responsible for starting, stopping, and controlling the speed of the variable target. When rotated all the way counterclockwise, it is set in the "off" position. As the rheostat knob is turned in the clockwise direction, the target begins moving in the set direction. As the knob continues to be rotated clockwise, the speed of the variable target will increase. To summarize, target movement is begun by rotating the knob clockwise, increasing speed as needed. All movement is stopped simply by rotating the knob counterclockwise into its "off" position.

Procedure:

Subjects read and signed the informed consent form, gave a brief history, then completed the entrance tests. All entrance testing was administered under standard room illumination and utilized standardized test instructions.

Visual acuities were taken first, monocular and binocular at six meters, utilizing standard optometric procedure. Determination of the preferred sighting eye followed. Subjects were asked to stand and view a relatively fine target across the room. Holding their arms extended directly in front of them, they were asked to overlap their hands and form a small opening between their thumbs and forefingers. Sighting the distance target through the small opening, they were next instructed to slowly bring their hands towards their face, keeping the sighted target visible through the opening at all times. At the point when the subjects' hands reached their face, the examiner made note of the eye that was viewing the distant target through the opening; this eye was recorded as being the preferred sighting eye.

All binocular subjects were then screened for performance of distance stereopsis on the B-VAT test unit. To accomplish this, the subjects first placed the B-VAT LCD goggles over their eyes and viewed the monitor across the room in front of them. Next, a group of four rings were displayed on the screen, one of them presented in crossed disparity that appeared to the observer as floating closer than the other three rings. The subject was asked to tell the examiner which ring he perceived as closer. This constituted one trial. The orientation of the disparate ring was then changed, and again the subject was asked to identify the floating ring. The disparity at the initial presentation was 240 sec arc. If the subject was able to correctly identify the disparate ring three times in four trials (75% accuracy), the disparity of the targets was decreased and the process was repeated. When a level of disparity was reached where the subject could no longer correctly identify the disparate stimulus on 75% of trials, the testing was stopped. The threshold was recorded as the smallest disparity where 75% accuracy was achieved. Upon completion, subjects were led into a different room to complete the actual experimental testing.

Depth perception was evaluated using the Howard - Dolman apparatus described previously. Each subject was seated in an adjustable height chair placed six meters from the stationary target housed inside the testing apparatus. The subject was then raised or lowered until the lateral canthus was aligned with a mark on a pole next to them; this mark corresponded to the exact height of the two targets they would be viewing. Next, through random determination it was decided in which direction the movable target was to be offset from the stationary target for each trial. Binocular subjects were randomly assigned to either Group OB or Group B at this time.

After the conditions were assigned, a standardized set of test instructions (Appendix B) was read to each participant, explaining the use of the remote as well as the specific testing procedure. Following these verbal instructions, a small model was used to illustrate the procedure. Subjects were also notified that they would be timed and, therefore, should make all judgments as quickly as possible without sacrificing accuracy. The experimenter placed the apparatus so that the stationary target within was at a distance of six meters from the viewer. The subject was then asked to manipulate an electric remote control to move the identical variable target from a starting point either closer or further from the stationary target. The starting position of the movable target was either +/- 0.20 meters from the stationary target (Figure 4.0). The subject's goal was to adjust, as quickly as possible, the movable target to the point where it was perceived to be at the same distance as the set target.

Participants were allowed to utilize any head movements necessary while making their respective judgments. Each participant completed four trials: twice with the movable object started at a further distance than the stationary target, and twice with the movable object presented closer. In all instances the view opening of the apparatus remained closed to the viewer while the variable target was reset between trials.

When aligning the two targets a specific protocol was followed. From its displaced starting point, each target could be moved in only one direction - towards the stationary target. The subject could stop the target's movement and pause to make any required judgments. Once those judgments were made, the subject was to continue the movement of the target in the same direction as before. The target could only be stopped or continued in the same direction. At no time was the subject allowed to reverse the direction of the movable target, or rock the target forward and reverse to arrive at the appropriate end point. With these rules in mind, the subject was instructed to stop the target where it was first deemed to be at the same distance from him as the stationary target. Following the completion of this task, subjects were again required to start the target moving in the same direction, and move it to the point where it was first perceived as being no longer aligned.

At the conclusion of the auditory instructions and model demonstration, the attention of the subject was drawn to the device before them across the room. An eye patch was now placed on the non-preferred sighting eye of those individuals assigned to Group OB. The opening to the apparatus was covered at this point. The subject was instructed that they would be given one practice trial. The practice trial was always run with the movable target placed 25 cm further away than the stationary target. The examiner then asked if the subject was ready to begin. When instructed, the apparatus cover was removed and the testing sequence was begun. At the moment the two targets became visible to the subject a stopwatch was started. The subject moved the target to the point of perceived alignment and said "Now!". Immediately, the timer was stopped, the opening to the device closed, and the time and accuracy data recorded. On cue by the examiner, the cover was again lifted and the subject continued moving the target to the position at which the two targets were perceived to be no longer aligned. At this point, the target was stopped and the subject notified the examiner. The door to the view opening was lowered and the final position of the movable target was recorded, completing one trial.

After trial number one, the examiner reset the movable target to the randomly assigned starting position for trial number two. In the same manner as the first, three more trials were completed. Upon completion of the fourth trial, the remote was set aside, the eye patch, if necessary, was removed, and the subject was released.

Thus, six types of data were gathered for analytical purposes: visual acuities, stereopsis, duration of monocular vision (when relevant), linear separation of the respective targets in millimeters at the point of perceived alignment, elapsed time, and the distance between the point at which the two targets were perceived to be aligned and the point at which they were first perceived as no longer aligned (the relative range through which the target could move while still being perceived as aligned).

Data Analysis:

Descriptive statistics were generated for Groups B and OB in the areas of accuracy, time, and "equal" response range. Two-tailed t-tests were performed to examine the significance of the difference in performance between Groups B and OB. The results of the two subjects comprising group M (M1 and M2), were compared individually to the mean measures of Groups B and OB. Finally, Group B and Group OB were examined separately to determine if significant correlation existed between any of the following variables: accuracy, time, "equal" response range, stereoacuity, and acuity OD, OS, and OU.

RESULTS:

A summary of the mean performance data of Groups B, Group OB, and Subjects M1 and M2 is presented in Tables 1.0 - 3.0, and illustrated in Figures 7.0 - 9.0.

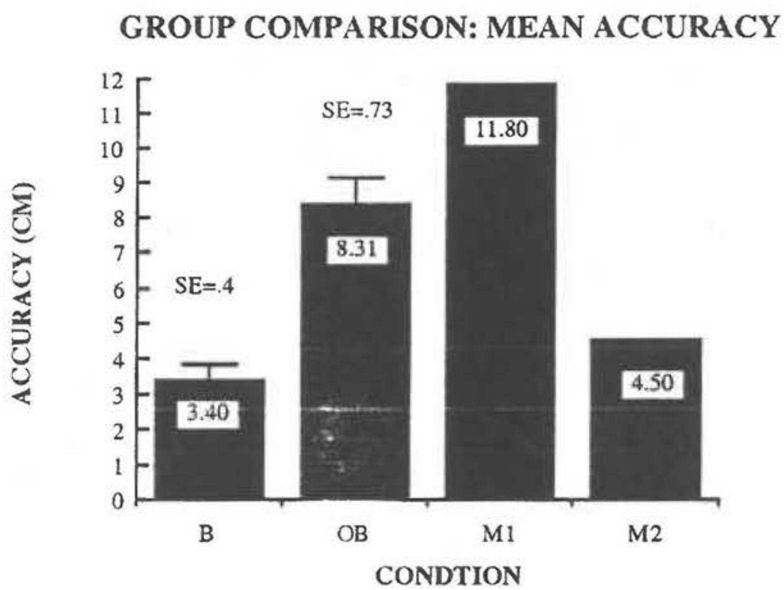
Examining accuracy alone (Table 1.0), there is an obvious and significant difference ($p= 0.0001$) in the performance of those subjects allowed to remain binocular versus their patched counterparts. Accuracy scores are based on the absolute values of the separation of the two targets. While the occluded binocular subjects scored a mean accuracy of 8.41 cm., the subjects remaining binocular scored a mean accuracy of 3.40 cm. The two monocular subjects varied greatly in their performance. Subject M1 had a mean accuracy of 11.8 cm. which placed him well below the marks established by the two groups of binocular individuals. On the other hand, Subject M2 demonstrated a mean accuracy of 4.50 cm., much better than the occluded binocular subjects, and only slightly less accurate than the binocular group (Figure 7.0). Though no statistics were generated about the differences in occurrence of errors relative to fore or aft starting position and the relationship to overestimation or underestimation of the target distance, the examiner noticed that performance seemed much less accurate and more variable when the movable target was started at a position closer than the stationary target.

Table 1.0: Accuracy

Condition:	Count:	Mean:	Std. Dev.:	Std. Error:
Group B	21	3.40 cm	1.83	.40
Group OB	18	8.41 cm	3.08	.73
M1	1	11.80 cm	-	-
M2	1	4.50 cm	-	-

T-Test (Group B vs. Group OB): T = 6.28, prob. (two-tailed) = .0001

Figure 7.0



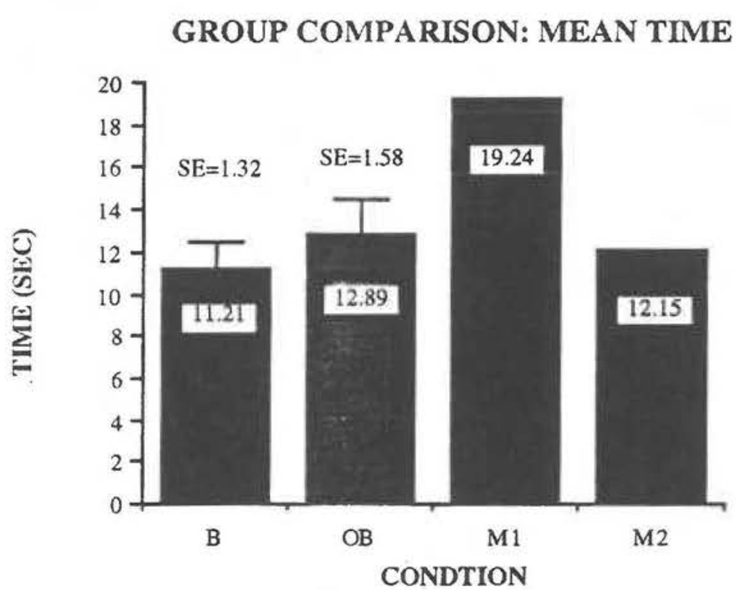
Next, the mean times of Groups B and OB show times of 11.21 seconds and 12.89 seconds respectively (Table 2.0). This small difference in performance was not found to be significant (p=0.415). Subject M1 took an average time 19.24 seconds to complete the timed period. This increased judgment time, however was not mirrored by subject M2. Again, displaying a degree of variability among the monocular subjects, M2 had a mean time relatively equal to Groups B and OB of 12.15 seconds (Figure 8.0).

Table 2.0: Time

Condition:	Count:	Mean:	Std. Dev.:	Std. Error:
Group B	21	11.21 sec.	6.03	1.32
Group OB	18	12.89 sec.	6.71	1.58
M1	1	19.24 sec.	-	-
M2	1	12.15 sec.	-	-

T-Test (Group B vs. Group OB): T = 0.82, prob. (two-tailed) = 0.415

Figure 8.0



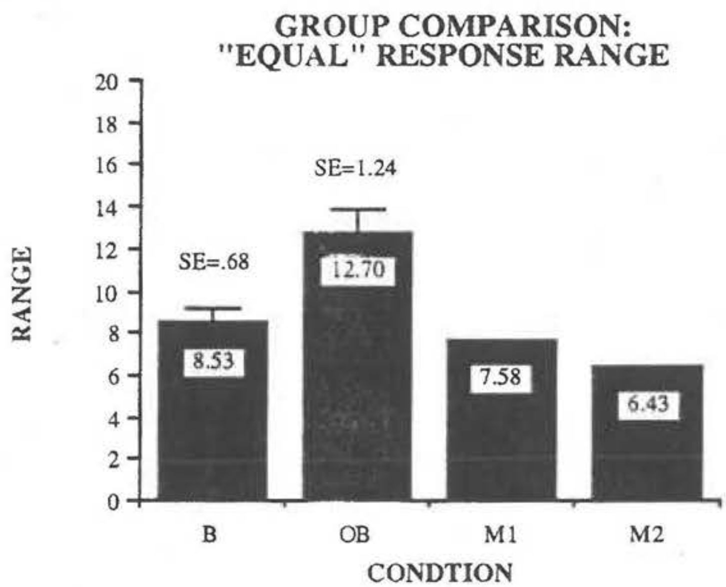
Further, the mean "equal" response ranges show both monocular individuals to have smaller limits than either the binocular or occluded binocular subjects (Table 3.0). M1 and M2 had ranges of 7.58 cm. and 6.43 cm., respectively. The difference between the ranges of Group B and Group OB proved significant (p=0.004). A range of 8.54 cm. was measured for the binocular subjects. However, unlike the adapted subjects M1 and M2, the mean range climbed to 12.70 cm. when individuals were denied adaptation to the monocular state, demonstrated by Group OB (Figure 9.0).

Table 3.0: "Equal" Response Range

Condition:	Count:	Mean:	Std. Dev.:	Std. Error:
Group B	21	8.54 cm	3.11	.68
Group OB	18	12.70 cm	5.25	1.24
M1	1	7.58 cm	-	-
M2	1	6.43 cm	-	-

T-Test (Group B vs. Group OB): T = 3.07, prob. (two-tailed) = 0.004

Figure 9.0



Surprisingly, no significant correlations were found when the individual variables within Groups B and OB are analyzed. In this study there appear to be no significant correlations between accuracy, speed of adjustment, stereoacuity and visual acuity. The specific correlation values among the different variables are shown in Tables 4.0 and 5.0. Due to the small population of monocular subjects, no correlations can be made using any of the monocular data.

TABLE 4.0: Correlation Matrix, Group B

	STEREO	ACCUR...	TIME	RANGE	ACUITY OD	ACUITY OS	ACUITY OU
STEREO...	1	-	-	-	-	-	-
ACCUR...	.254	1	-	-	-	-	-
TIME	-.034	-.119	1	-	-	-	-
RANGE	.393	.333	-.336	1	-	-	-
ACUITY OD	-.01	.133	-.222	.282	1	-	-
ACUITY OS	.143	.214	-.118	.04	.407	1	-
ACUITY OU	-.141	.345	-.224	.272	.693	.524	1

Table 5.0: Correlation Matrix, Group OB

	STEREO	ACCUR...	TIME	RANGE	ACUITY OD	ACUITY OS	ACUITY OU
STEREO...	1	-	-	-	-	-	-
ACCUR...	-.031	1	-	-	-	-	-
TIME	.139	.241	1	-	-	-	-
RANGE	.347	-.205	-.401	1	-	-	-
ACUITY OD	.264	-.188	.238	.093	1	-	-
ACUITY OS	.049	.09	.329	-.076	.338	1	-
ACUITY OU	.076	.173	.439	-.325	.584	.64	1

DISCUSSION:

Two hypotheses were studied concerning the relative accuracy and speed at which individuals having only one eye could complete a depth judgment task. First, an assumption was made that adapted monocular individuals would prove as accurate as a group of binocular subjects. Further, it was stated that both groups would be significantly more accurate than a group of binocular subjects having to perform with one eye patched. Second, it was hypothesized that both the adapted monocular and the occluded binocular subjects would be less efficient than the subjects performing binocularly.

A common misconception of many practitioners is that monocular individuals are by far inferior to their binocular counterparts in perceiving depth. I believe that many of these misconceptions are the result of overgeneralization of available research or bias from personal experience. First, most studies examining monocular individuals utilize patching of binocular people and then attempt to extrapolate those results. Also, many practitioners call on personal experiences. That is, the binocular individual sometime in life has either experimented with or been forced into a situation of monocular viewing. Under this new viewing situation, the individual quickly comes to realize the value of stereopsis in performing depth discrimination tasks. As a result of these experiences, a parallel is drawn regarding a perceptual inadequacy that a monocular person must exhibit in performing similar tasks in everyday life. In many cases, nothing could be further from the truth. Neither of the examples take into account the adaptations that occur when monocular people are forced into a situation and must learn to perceive the world in a new way, utilizing other sources of information than would be necessary if living with the use of two well-functioning eyes.

In this experiment, binocular subjects significantly outperformed the occluded binocular subjects, as has been shuwn in previous research. The results of the two monocular subjects varied markedly. Subject M1 was far less accurate than the marks set by Groups B and OB, possibly leading an examiner to the conclusion that some individuals never adapt fully to loss of an eye. It might also indicate that, though limited by the inability to use stereopsis, the use of two healthy eyes capable of functioning together somehow provides an advantage in perceiving depth even under monocular conditions. However, while not quite reaching the level established by group B, Subject M2 demonstrated that certain individuals adapt over time and achieve a good degree of accuracy when judging depth. Individual examples of this have been demonstrated many times in many different situations. There are instances where functionally monocular athletes, such as former NFL wide receiver Wesley Walker, have competed with and often outperformed other binocular athletes in dynamic sports that would seem to favor the binocular athlete. These individual adaptations may also help to explain one study showing the ability of monocular pilots to perform a landing task better than their binocular counterparts[6]. The only conclusion regarding accuracy that can be drawn from this study is that monocular individuals do exist who have the ability to make accurate depth judgments when provided with the appropriate depth cues. However, no generalization can be made to the monocular population as a whole nor can there be arrived at any conclusions about the time it takes these individuals to adapt to making depth judgments minus stereopsis. Therefore, the first hypothesis stated in this paper can not be proved.

Time is the variable by which efficiency was measured in this project. Upon comparison of Groups B and OB, there was no significant difference in the time required to make the initial depth judgment. Though Subject M1 took a greater time making his judgment, the time of Subject M2 was comparable to the other two groups. Thus, as measured by this study, there seems to be no significant benefit to either binocular or monocular state when evaluating the speed of the judgment. Given this outcome, the data were next analyzed to determine if there existed a significant correlation between accuracy and the speed at which the judgment was made. Again, there existed no notable relationship. In other words, neither the ocular status of the subjects nor the time taken to make the judgment was linked to the overall accuracy of that judgment. Hence, this research cannot support any significant relationship between efficiency and ocularity in depth discrimination. Therefore, the second hypothesis stated in this paper cannot be proven. Instead, the way each individual mobilizes his system to arrive at a judgment is dependent on the physiologic, physical, and mental make up of the subject as opposed to ocularity.

Subjects were asked two make two judgments. The moving target was to be stopped where it first appeared aligned, or "equal", with the stationary target, and again when they first perceived the targets as no longer being "equal". This resulted in a range that the target could be moved without an appreciable change in the perceived depth of the target. In other words, it provided a somewhat loose measure of the "just noticeable difference", or JND, a relative measure of the sensitivity of the combined visual and perceptual systems. Like accuracy, a significant difference between Group B and OB was shown, with the binocular subjects having the smaller range. Both monocular subjects had smaller "equal" response ranges than Groups B and OB, indicating the possible presence of an increased sensitivity somewhere within their individual systems. However, such a proposed sensitivity does not necessarily manifest itself in increased depth perceptual accuracy. No significant correlation was found between the "equal" response range and the accuracy measurements in either Group B or Group OB. Once again, no generalization can be made to a larger monocular population. Only further research with large subject numbers can substantiate or refute these individual findings, to determine if a significant difference does exist when compared to other populations.

Lastly, statistical analysis of all remaining variables was conducted to determine the existence of any significant correlations. No significant correlations were found between binocular or monocular acuities, stereoacuity, range, time, or accuracy.

The implications of monocular research are numerous. Educationally, it is essential that the limitations of the monocular individual be accurately portrayed, so that both clinicians and patients know the reasonable expectations and opportunities presented to this large sector of the visual population. Furthermore, a strong experimental base must be built, upon which further studies can be explored; specifically, visual training as applied to the monocular patient. Appropriate training may prove valuable both in the adjustment to a new daily lifestyle as well as the enhancement of athletic performance, both recreational and competitive. Lastly, further research is needed in the areas of binocular enhancement through solely monocular training. Such training could begin to offer another way to assist all people in the obtaining the most efficient visual systems possible.

REFERENCES

1. Brady FB. A singular view: the art of seeing with one eye. Oradell, NJ: Medical Economics, 1972.
2. Gogel WC, Tietz JD. The effect of perceived distance on perceived movement. Perception and Psychophysics. 1974, 16: 70 - 78.
3. Sheedy JE, Bailey IE, Buri M, Bass E. Binocular vs. monocular task performance. American Journal of Optometry and Physiological Optics. 1986, 63: 839 - 846.
4. McKnight AJ, Shinar D, HIlburn B. The visual and driving performance of monocular and binocular heavy-duty truck drivers. Accident, Analysis, and Prevention. 1991, Aug, 23(4): 225 - 227.
5. Kochhar DS, Fraser TM. Monocular peripheral vision as a factor in flight safety. Aviation, Space, and Environmental Medicine. 1978 May, 49: 698 - 706.
6. Lewis CE Jr., Blakeley WR, Swaroop R, Masters RL, McMurty TC. Landing performance by low time private pilots after the sudden loss of binocular vision: Cyclops II. Aviation, Space, and Environmental Medicine. 1973, Nov, 44: 1241 - 1245.
7. Groslight JH, Fletcher HJ, Masterton RB, Hagen R. Monocular vision and landing performance in general aviation pilots: Cyclops revisited. Human Factors. 1978, Feb, 20(1): 27-33.
8. von Noorden GK. Binocular vision and ocular motility: theory and management of strabismus. C.V. Mosby Co., St. Louis, Mo., 1990.
9. Jones RK, Lee DN. Why two eyes are better than one: the two views of binocular vision. J Exp Psychol (Hum Percept). 1981, 7: 30 - 40.
10. Gonzalez EG, Steinbach MJ, Ono H, Wolf ME. Depth perception in children enucleated at an early age. Clin. Vision Sci. 1989, 4 : 173 - 177.

APPENDIX A

INFORMED CONSENT FORM

INSTITUTION

A.	Title of project:	OCULARITY AND ADAPTATION IN A DEPTH DISCRIMINATION TASK
B.	Principal investigator:	Brian S. Duvall (503) 357-5382
C.	Advisor:	Bradley Coffey, O.D. 357-6151 ex. 2280
D.	Location:	College of Optometry, Pacific University Forest Grove and Portland, Oregon
E.	Date:	1992

I. DESCRIPTION OF PROJECT

This research project is designed to examine how accurately and quickly a person can make a relative distance judgment depending on whether they are viewing with one eye or two. Subjects will be divided into three groups: 1) those who have or use only one eye, 2) those who see with both eyes but will have one eye patched, and 3) those who will be allowed to use both eyes while making their judgments. Each subject will have his/her judgments measured after completing four trials on a specific apparatus designed to measure depth perception. Data will be analyzed looking at differences that may exist between the groups and how they view the target.

II. DESCRIPTION OF RISKS

All measurements used in this study are achieved using devices that are commonly employed in routine optometric evaluation. Therefore, risk to subjects is no greater than that associated with routine vision care.

During the experiment, each subject will be required to make some fine judgments. As a result, individuals may experience some small degree of fatigue or eyestrain. Any symptoms that do occur should be mild and short lived.

III. DESCRIPTION OF BENEFITS

Research will serve to increase the understanding of the abilities and adaptations made in perceiving depth when confronted with the long term use of one eye, either physically or functionally.

APPENDIX A

IV. RECORDS

Records of this project will be maintained in a confidential manner and no name-identifiable information will be released.

V. COMPENSATION AND MEDICAL CARE

If injured in this project, it is possible that you will not receive compensation or medical care from Pacific University, the experimenters, or any organization associated with the experiment. Responsible measures will be taken to prevent injuries from occurring.

VI. INQUIRIES

The experimenters will be happy to answer any questions that arise anytime during the course of the study. If you are not satisfied with the answers you receive, please contact Dr. James Peterson at (503) 357-0442. During participation in this research, you are not considered a Pacific University clinic patient or client. Therefore, all inquiries should be directed to the researchers or faculty advisor who will be solely responsible for any treatment (except in cases of emergency). You will not be receiving complete vision or eye health care as a result of participation; thus your regular program of eye, vision, and health care must be maintained.

VIII. FREEDOM TO WITHDRAW

You are free to withdraw your consent and to discontinue participation in this project or activity at any time without prejudice to you.

I have read and understood the above. I am 18 years of age or over (or this form is signed for me by my parent or guardian).

Printed name ______________________________

Signed ______________________ Date ______________

Address ______________________ Phone ______________

City ______________________ State/Zip ______________

Name and address of a person not living with you who will always know your address.

Appendix B

Key to Figures 1.0 - 6.0

LABEL	DESCRIPTION
Side " A " :	Front Of Wooden Housing
Side " B "	Side Of Wooden Housing
Side " C "	Top Of Wooden Housing, Painted Black
Side " D "	Back Of Wooden Housing
Side " E "	Side Of Wooden Housing (Not Shown)
Side " F "	Bottom Of Wooden Housing (Not Shown)
Distance A	Length Of Wooden Housing = 24 inches
Distance B	Width Of Wooden Housing = 16 inches
Distance C	Height Of Wooden Housing = 8 inches
Distance D	Width Of Hood = 16 1/8 inches
Distance E	Length Of Hood = 24 1/8 inches
Distance F	Height Of Hood = 8 inches
Distance G	Width Of Viewing Area = 8 inches
Distance H	Height Of Viewing Area = 4 inches
Distance I	Overall Height Of Apparatus, Hood Attached = 16 inches
Distance J	Separation Of Targets = 6 cm.
Distance K	Length Of Track Groove = 46 cm.
1.	Opening For Wired Remote
2	Measuring Scale
3.	Measuring Needle
4.	Motor Control Switch
5.	Lighting Control Switch
6.	Track Groove
7.	Stationary Target
8.	Variable Target
9.	Mounted Fluorescent Strip Lights (2)
10.	Opening For Powercord
11.	Runner
12	Track
13.	Pulley System
14.	Kill Switch
15.	Motor And Attached Pulley
16.	Power Supply

Figure 1.0

External Appearance Of Apparatus (Without Hood)

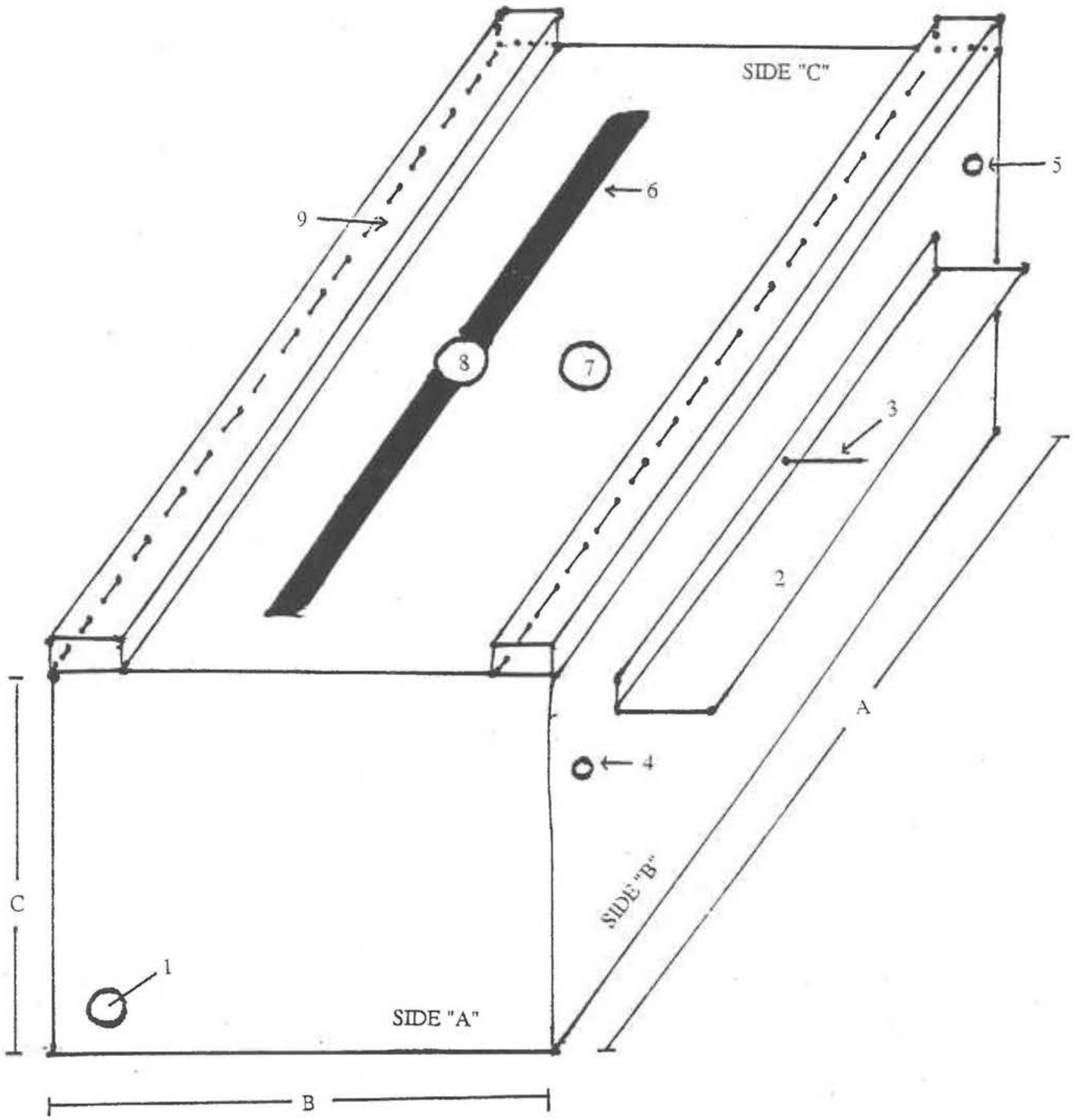


Figure 2.0

External Appearance Of Hood (Unattached)

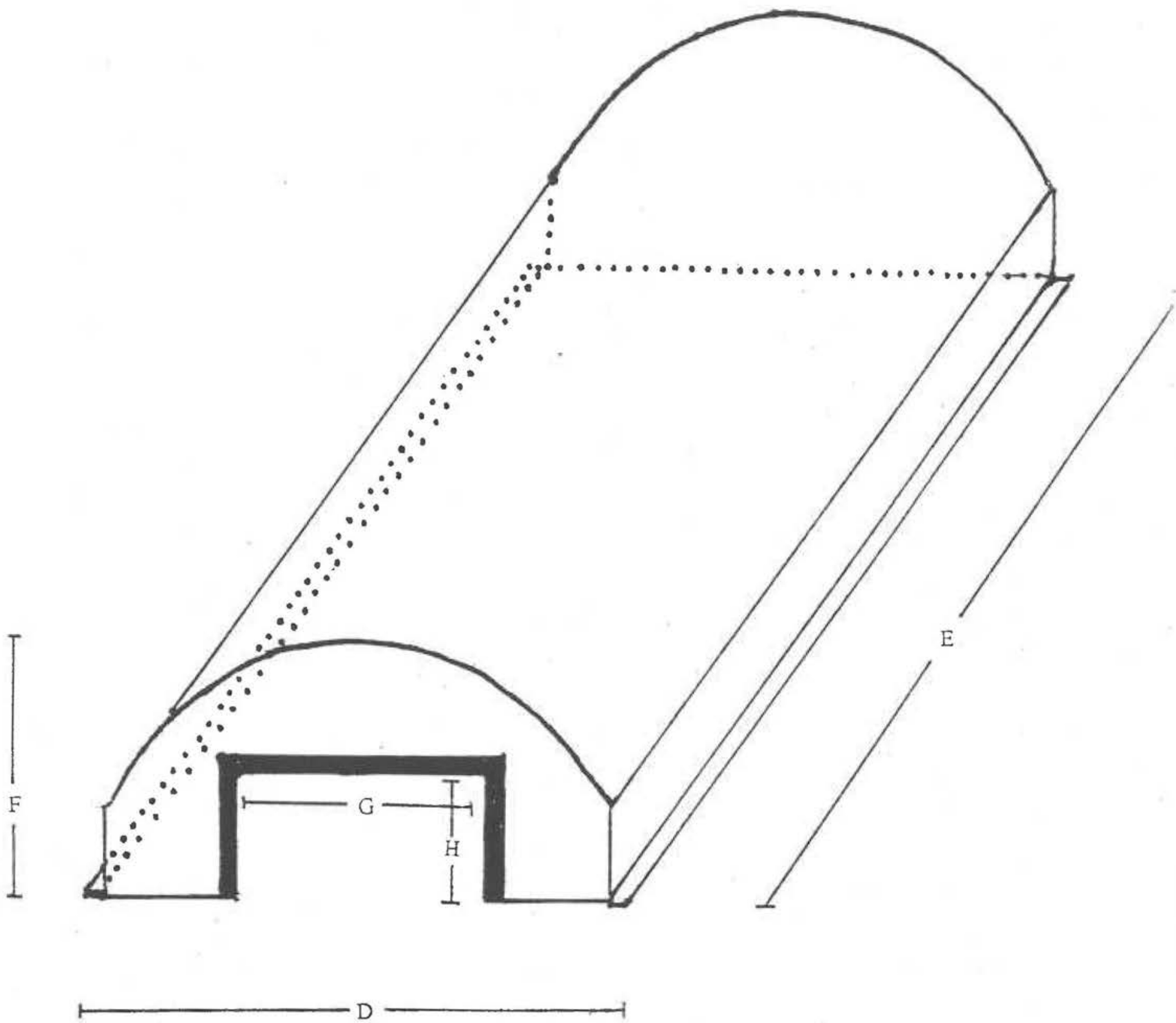


Figure 3.1

Front View Of Apparatus With Hood Attached

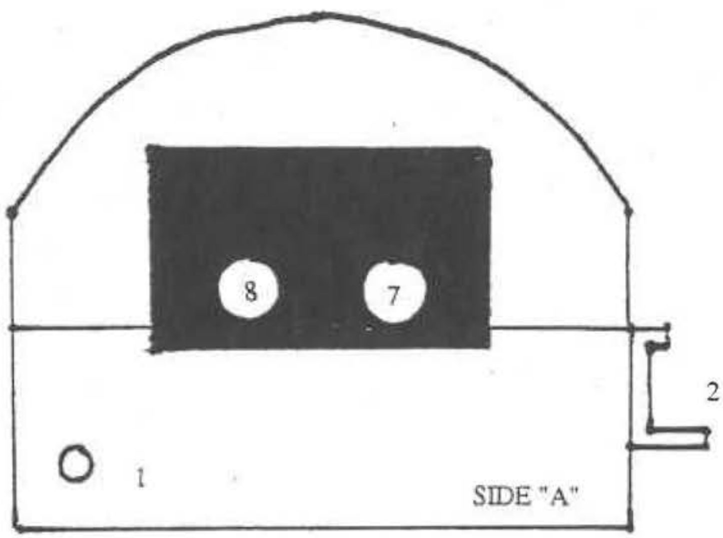


Figure 3.2

Back View Of Apparatus With Hood Attached

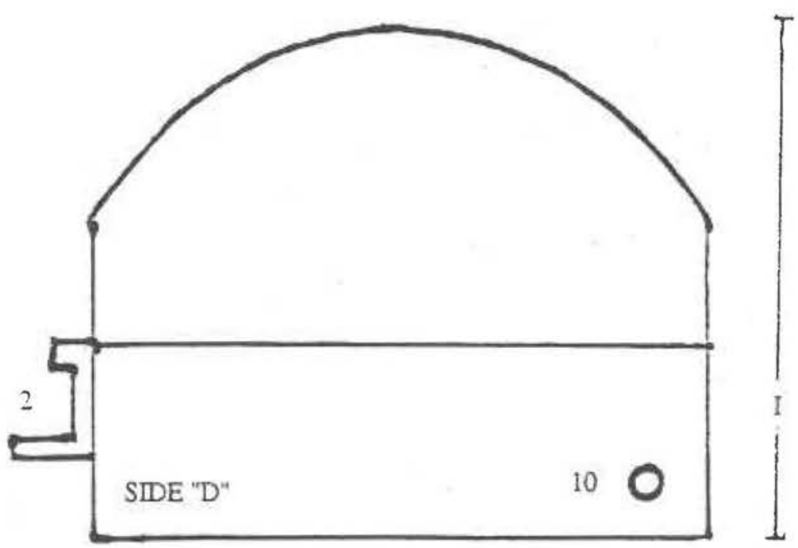


Figure 4.0

Top View Of Apparatus (Hood Removed)

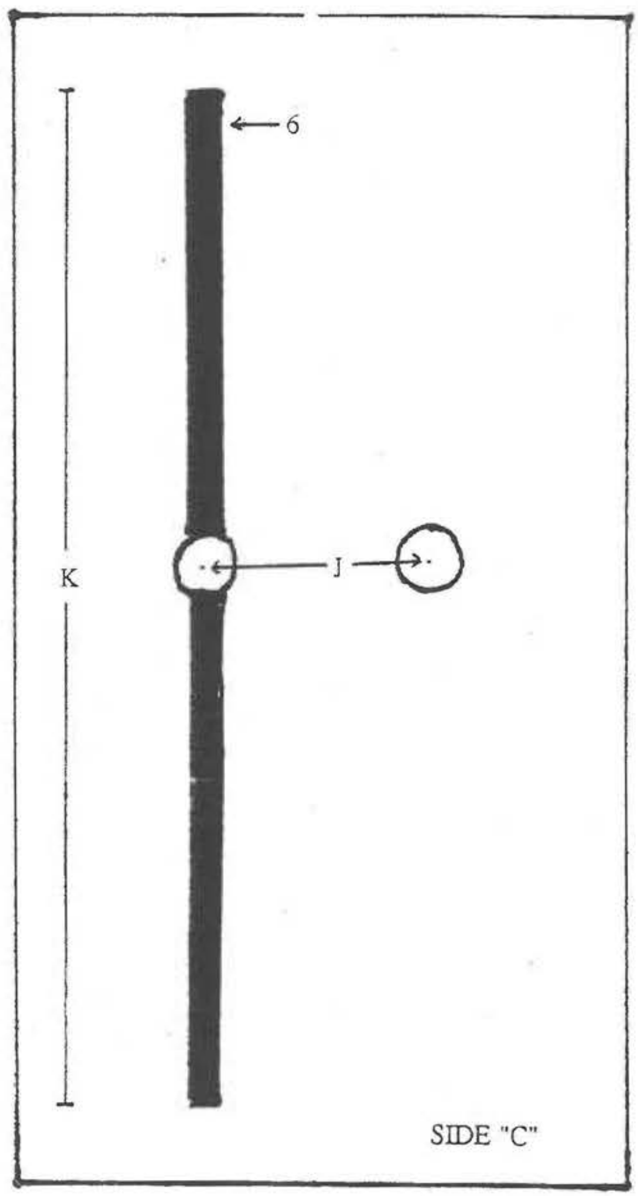


Figure 5.0

Top View Of Internal Workings (Side " C " Removed)

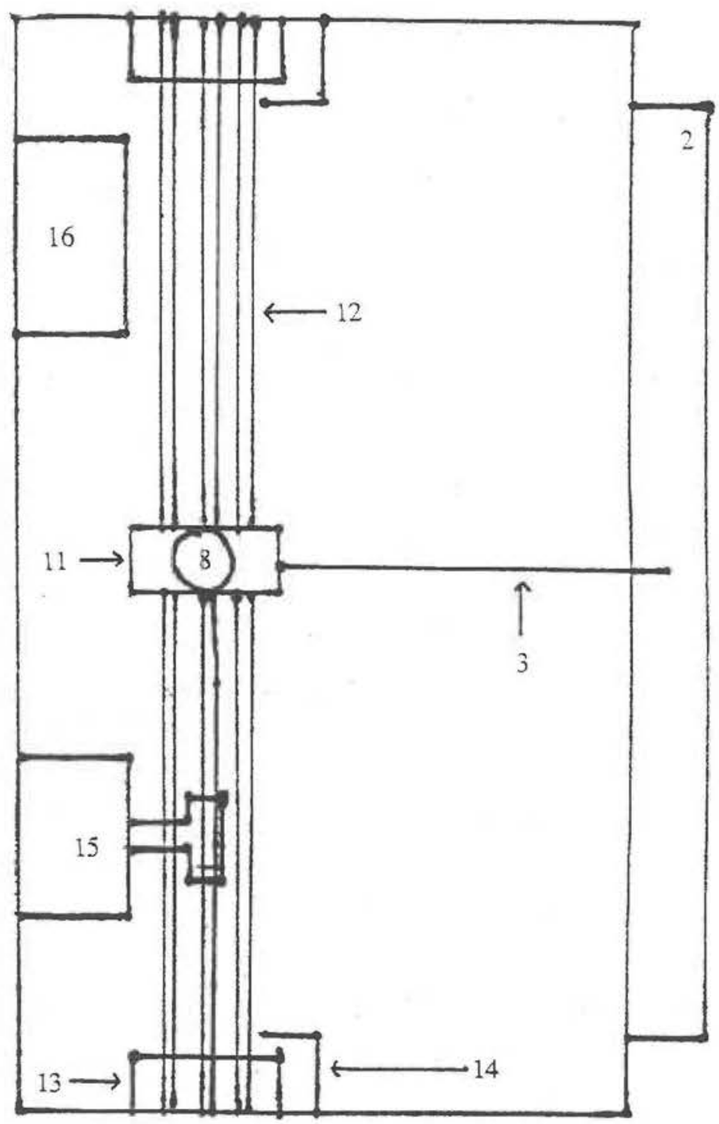
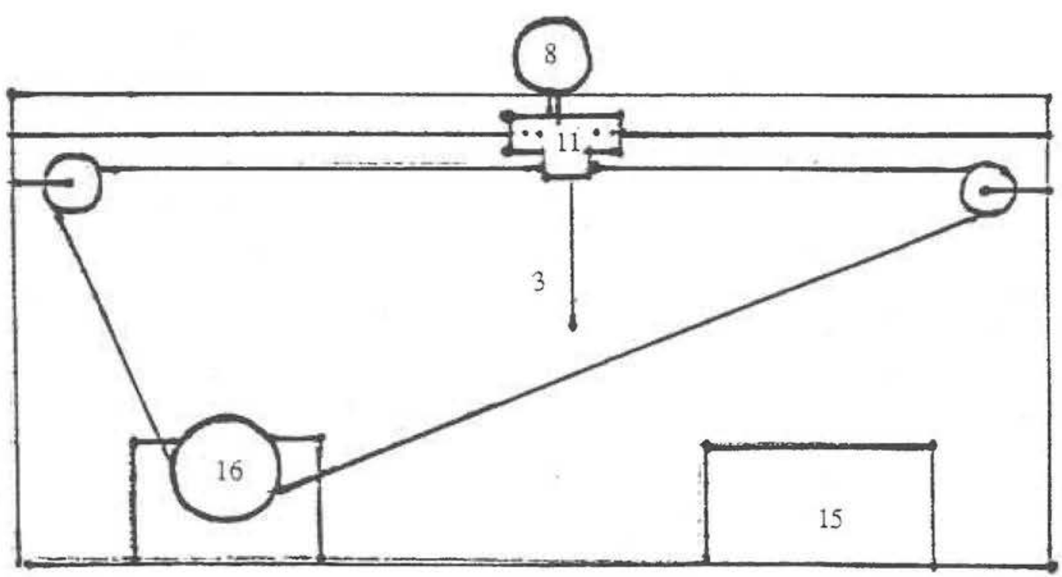


Figure 6.0

Side View Of Internal Workings (Side " B " Removed)



APPENDIX C

INSTRUCTIONS: Experimental Procedure And Use Of Controller For H-D Apparatus

" Inside the device across the room in front of you, there are two round targets. The targets will be set at different distances. The target on the right is stationary. You will be able to control the movable target on the left. The object of the test will be to align the two targets so they appear an equal distance away from you. *(Use model to demonstrate)*

Demonstrating: You will see two targets - a stationary target on the right and a movable target on the left. The movable target will either be set in front of or behind the stationary target. You will be first asked to align the targets, and then move them until they first appear no longer aligned.

(Hand subject controller). " The controller in front of you has a silver switch and a knob. These are used to control the movable target. The silver switch is used to control the direction of the movable target. The examiner will tell you where to set this switch. You will control only the knob. The knob will be used to start, stop and control the speed of the target. Turned all the way counterclockwise, the knob is off. Speed will increase as the knob is rotated clockwise.

" By rotating the knob left or right, you can start and stop the target as many times as you need to make the proper judgment. However, be aware, if you go to far you can not go back. Stop the target when the two targets appear aligned and notify the examiner.

" I then will block your view of the target while I make the readings. I will then uncover the targets and ask you to continue moving the target until it first appears to you as being no longer aligned. This completes the trial.

" You will be given on practice trial, and then asked to complete the same task four more times. You will be timed, so make your judgments both quickly and accurately."

APPENDIX D

PROTOCOL FOR TESTING: MODIFIED HOWARD DOLMAN APPARATUS

* set up apparatus and adjust lighting levels.

1. Have subject read and sign consent form.
2. Seat subject in exam chair facing BVAT.
3. Take distance visual acuity.
4. Determine subject's preferred sighting eye.
5. Place LCD goggles on subject.
6. Give instructions for ring float stereoacuity test.
7. Administer test.
8. Record stereoacuity results.
9. Lead subject into room two containing modified H-D apparatus.
10. Seat subject
11. Adjust chair height to align canthus with mark on pole.
12. Detrmine test condition for binocular paticipants. (random)
13. For subjects performing in either the monocular group or the occluded binocular group, place eyepatch over subject's non-preferred sighting eye. (*omit step 12 for subjects performing binocularly)*
14. Hand subject controller.
15. Instruct subject as to the testing procedure and proper use of controller.
16. Give test instructions.
17. Seat yourself at test apparatus.

TRIAL1 (randomly determine preset)

18. Offset movable <u>+/- 20.0 cm</u>.
19. Tell subject to get ready, and in which direction to set the silver switch.
20 Uncover the opening of the H-D device.
21. Tell subject to begin and start timer.
22. When subject reprts the targets to be alligned, stop timer.
23. Cover opening.
24. Record target offset.
25. Uncover opening and instruct the patient to continue until he no longer perceives the targets to be aligned.
26. Close opening and record offset; instruct subject to return switch to middle position.

TRIAL 2 (randomly determine preset)

27. Reset movable target to <u>+/- 20.0 cm</u>.
28. Repeat steps 18 - 25.

TRIAL 3 (randomly determine preset)

29. Reset movable target to <u>+/- 20.0 cm</u>.
30. Repeat steps 18 - 25.

TRIAL 4 (randomly determine preset)

31. Reset movable target to <u>+/- 20.0 cm</u>.
32. Repeat steps 18 - 25.

33. Have subject place controller down.
34. Remove Eyepatch.
35. Recheck that all findings have been recorded.
36. Thank subject very, very much with heartfelt sincerity and provide them with any further information.
37. Prepare for next subject or turn off apparatus.

APPENDIX E

DATA RECORDING FORM

NAME: ______________________ DATE:________

ADDRESS: ______________________________

PHONE: ______________ DATE OF BIRTH:__________

I. DISTANCE VISUAL ACUITY: OD: 20/ OS: 20/ OU: 20/

* If monocular, for how long? ______ years

II. PREFERRED SIGHTING EYE *(please circle one)* : OD OS

III. STREOACUITY (6m.): _____ arc seconds

IV. TEST CONDITION *(please circle one)* :
* If subject is binocular, randomize conditions #2 and #3.

1. Monocular
2. Binocular
3. Binocular-occluded

V. TRIALS:
* Randomize target preset

A. TRIAL 1:
1. Initial offset *(please circle one)* : +20.0 cm. -20.0 cm.
2. Time to "equal" response: ______ seconds
3. Offset at "equal" response: ______ cm.
4. Offset when "again disparate": ______ cm.

B. TRIAL 2:
1. Initial offset *(please circle one)* : +20.0 cm. -20.0 cm.
2. Time to "equal" response: ______seconds
3. Offset at "equal" response: ______ cm.
4. Offset when "again disparate": ______ cm.

C. TRIAL 3:
1. Initial offset *(please circle one)* : +20.0 cm. -20.0 cm.
2. Time to "equal" response: ______seconds
3. Offset at "equal" response: ______cm.
4. Offset when "again disparate": ______cm.

D. TRIAL 4:
1. Initial offset *(please circle one)* : +20.0 cm. -20.0 cm.
2. Time to "equal" response: ______ seconds
3. Offset at "equal" response: ______ cm.
4. Offset when "again diparate": ______cm.